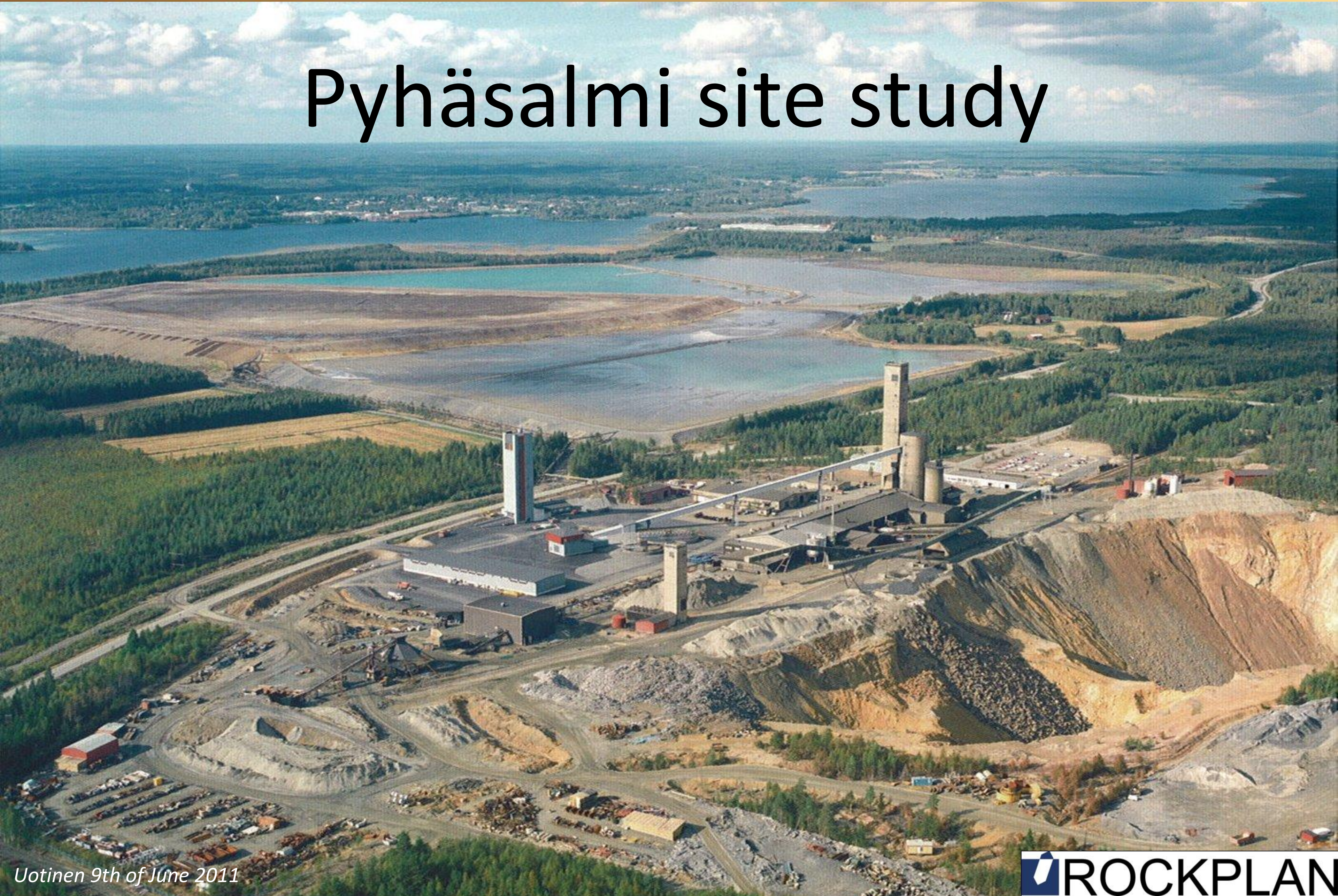

GLA2011

Pyhäsalmi site study



Uotinen 9th of June 2011

LAGUNA Design Study
Underground infrastructures and engineering (EU, FP 7)

TASKS OF ROCKPLAN:

DELIVERABLE 2.1

+ assisting in deliverable 2.8, 3.1...3.4

LAGUNA @ PYHÄSALMI, FINLAND

ROCKPLAN

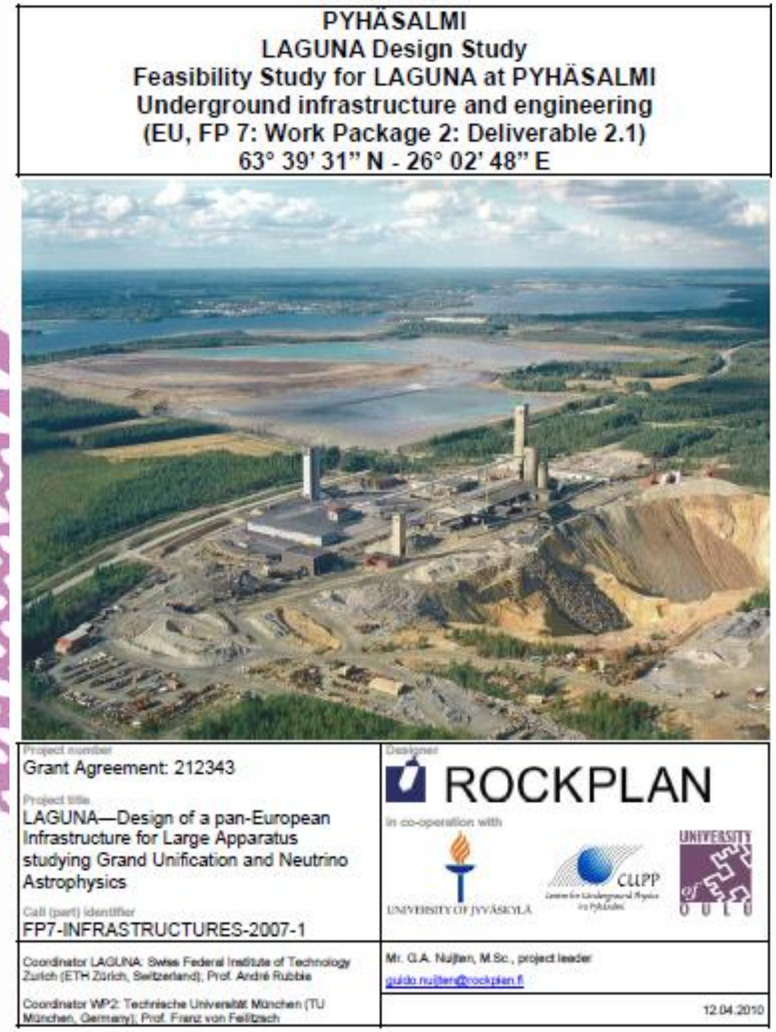
Deliverable 2.1

Site study of all LAGUNA options at Pyhäsalmi

Total of 279 pages

Three main parts:

G	**Glacier**
M	Memphys
L	Lena



PYHÄSALMI
LAGUNA Design Study
Feasibility Study for LAGUNA at PYHÄSALMI
Underground infrastructure and engineering
(EU, FP 7: Work Package 2: Deliverable 2.1)
63° 39' 31" N - 26° 02' 48" E

Project number
Grant Agreement: 212343

Project title
LAGUNA—Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification and Neutrino Astrophysics

Call (part) identifier
FP7-INFRASTRUCTURES-2007-1

Designer
ROCKPLAN
in co-operation with
UNIVERSITY OF JYVÄSKYLÄ
CUPP
UNIVERSITY of OULU

Coordinator LAGUNA: Swiss Federal Institute of Technology Zurich (ETH Zürich, Switzerland); Prof. André Rubbia

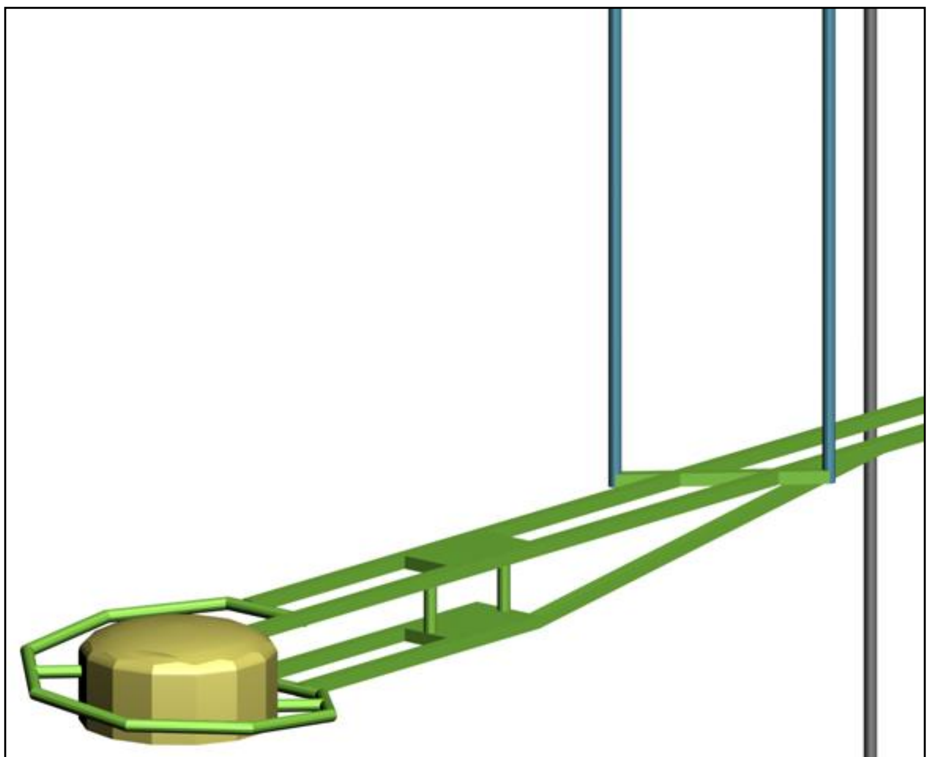
Coordinator WP2: Technische Universität München (TU München, Germany); Prof. Franz von Feilitzsch

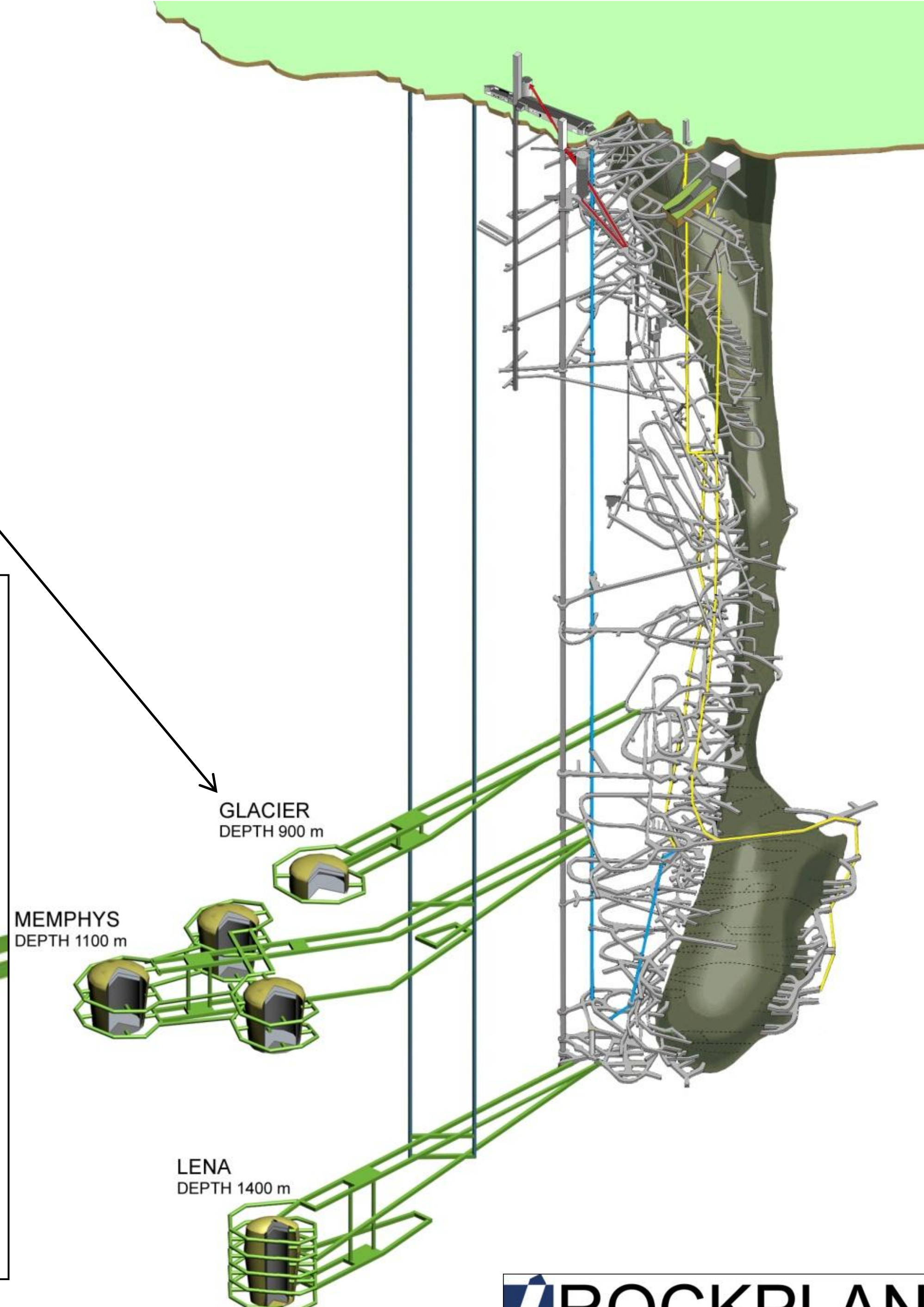
Mr. G.A. Nuijten, M.Sc., project leader
guido.nuijten@rockplan.fi

12.04.2010

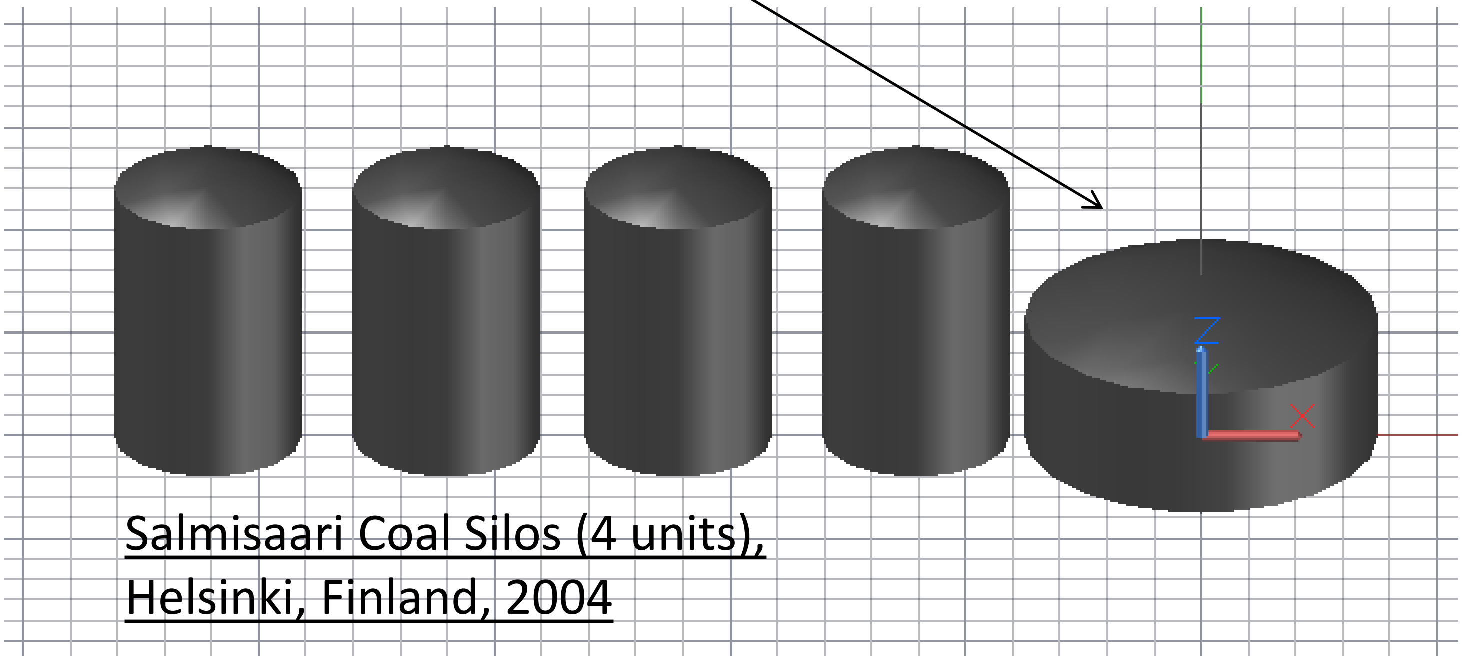
ROCKPLAN

Glacier in comparison





Glacier in comparison



Salmisaari Coal Silos (4 units),
Helsinki, Finland, 2004

Glacier in comparison

The world biggest (over 40 m) man-made underground caverns are:

Site	*Country*	***span***	*length*	*height*	*depth*	
Glacier		***75 m***	*75 m*	*38 m*	*900 m*	(planned)
Gjøvik Olympic Cavern Hall	Norway	**61 m**	91 m	25 m	40 m	
Tytyri Mine, chalk mine museum	Finland	**60 m**			110 m	
Salmisaari coal storage silos	Finland	**42 m**	42 m	65 m	50 m	ROCKPLAN
Leppävirta, cross country ski hall	Finland	**40 m**	100 m	10 m	15 m	ROCKPLAN
Super- Kamiokande, neutrino det.	Japan	**40 m**	40 m	55 m	1000 m	
Vihanti mine	Finland	**40 m**			180 m	

In Finland the size of the cavern is not at the upper limit of the rock mechanical stability.

So far no client has ever requested for bigger caverns.

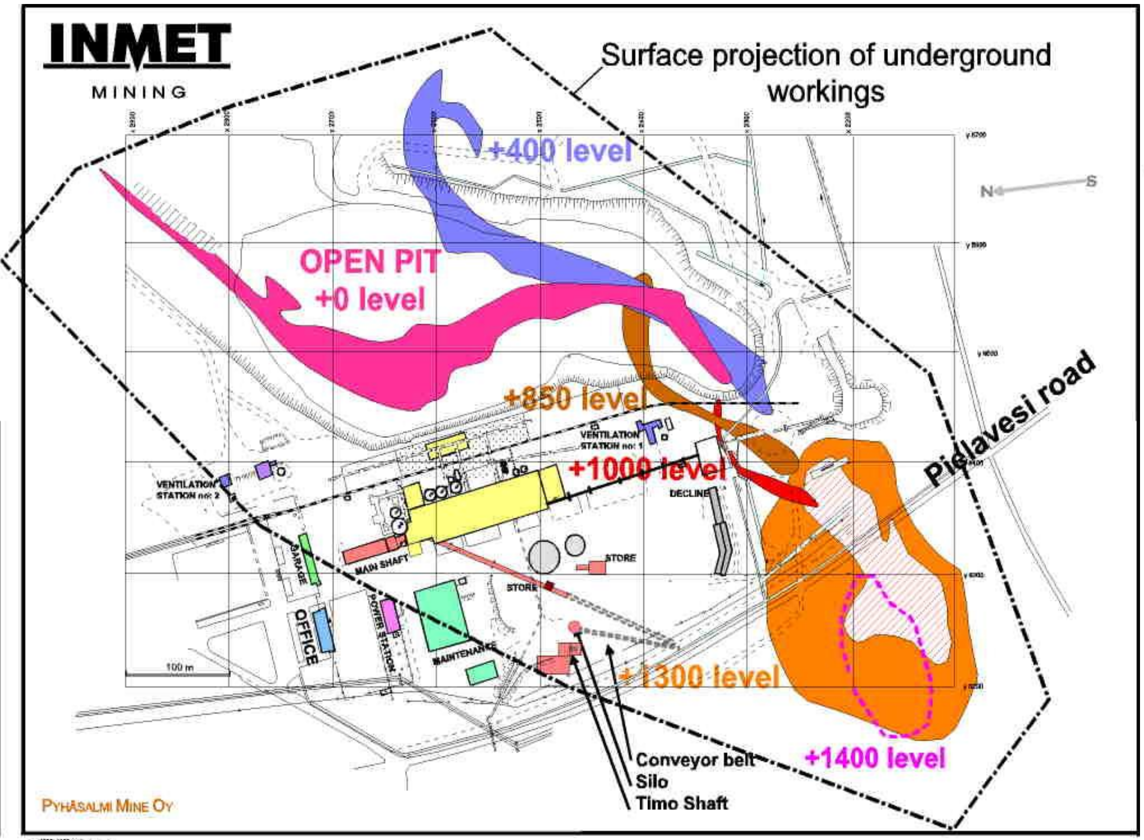
Location of Pyhäjärvi / Pyhäsalmi in Finland

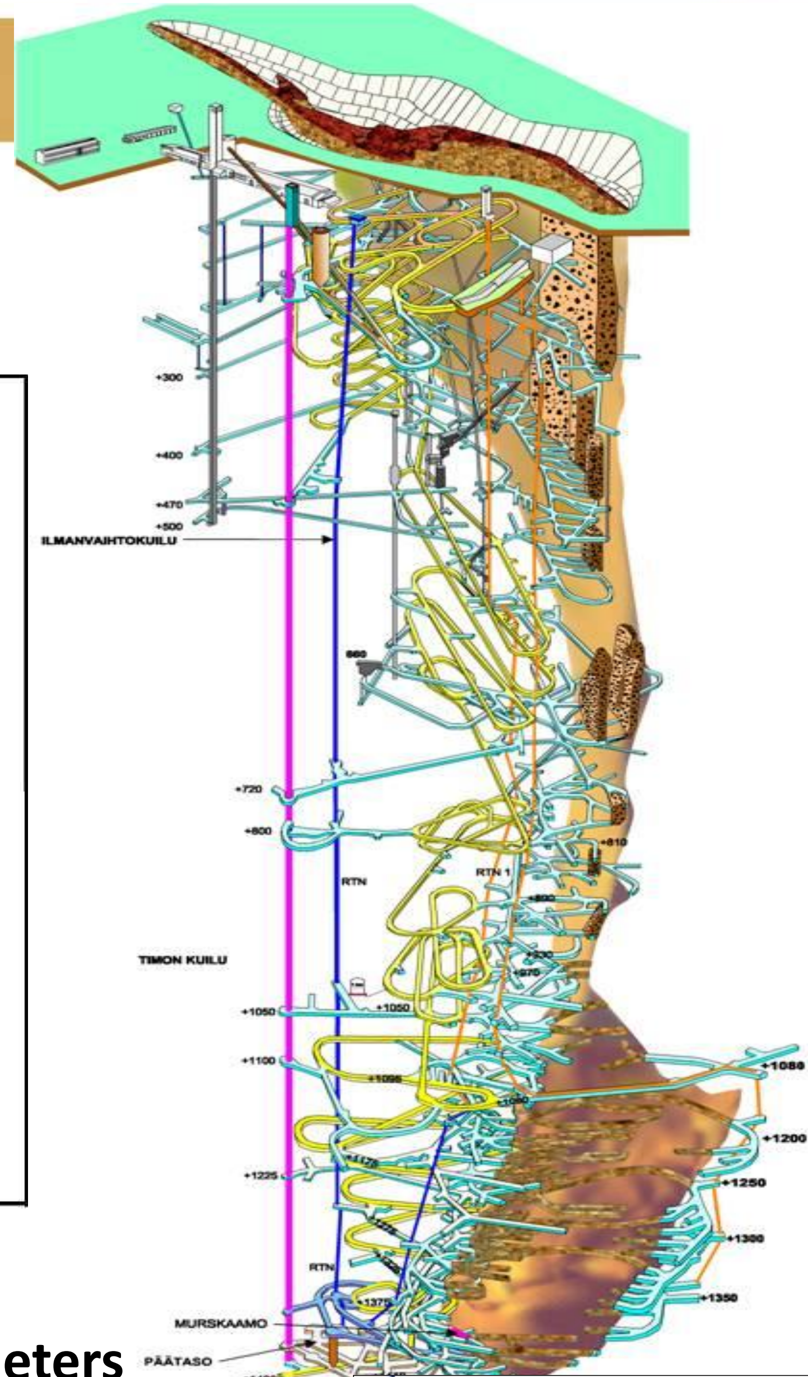
63° 39’ 31’’ N
26° 02’ 48’’ E

You are here now

KALLIOSUUNNITTELU OY
ROCKPLAN LTD

3-D impression of Pyhäsalmi mine





- 1440 meters

ROCKPLAN

Uotinen 9th of June 2011

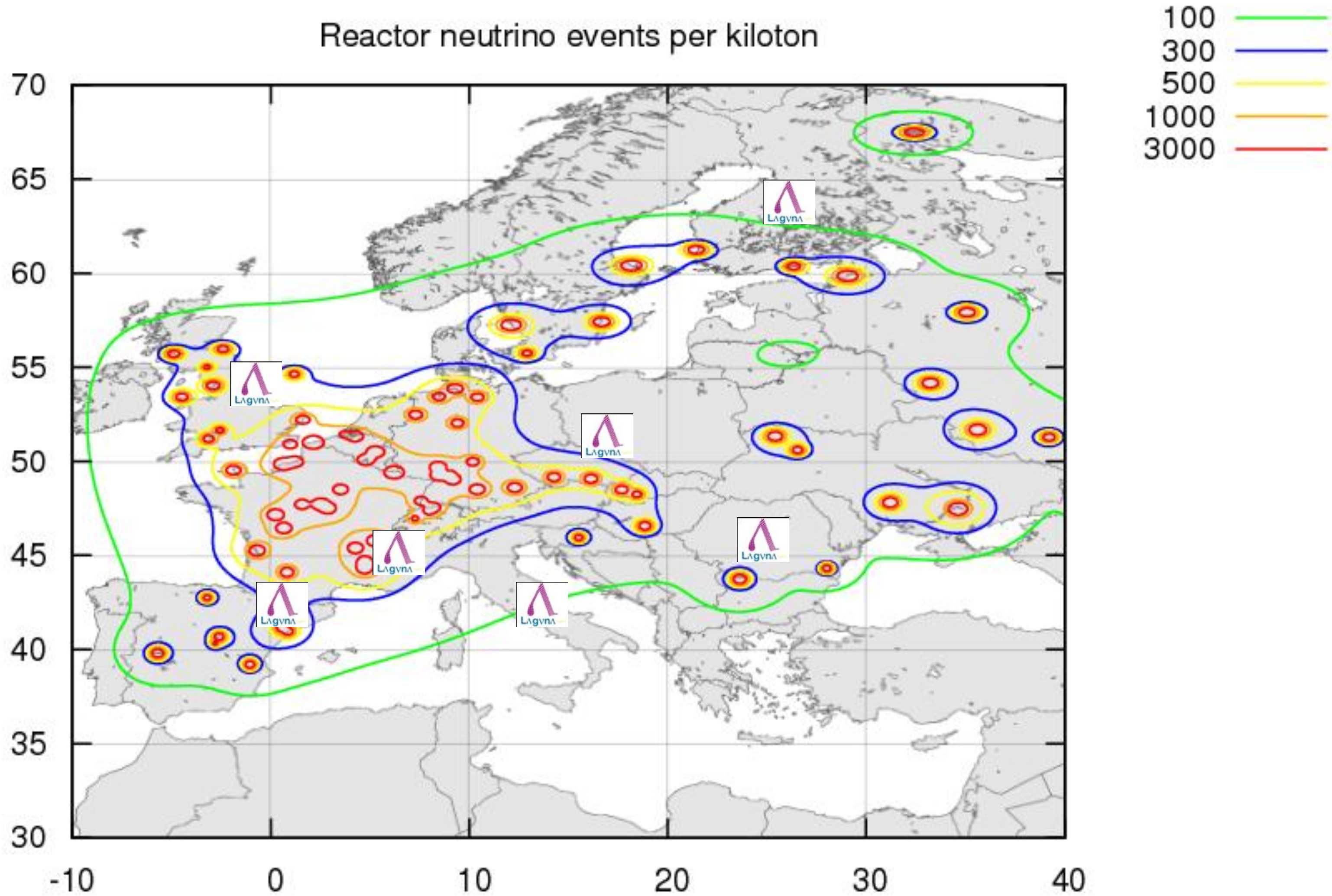
LAGUNA, purpose:

1) to study the feasibility of the considered experiments

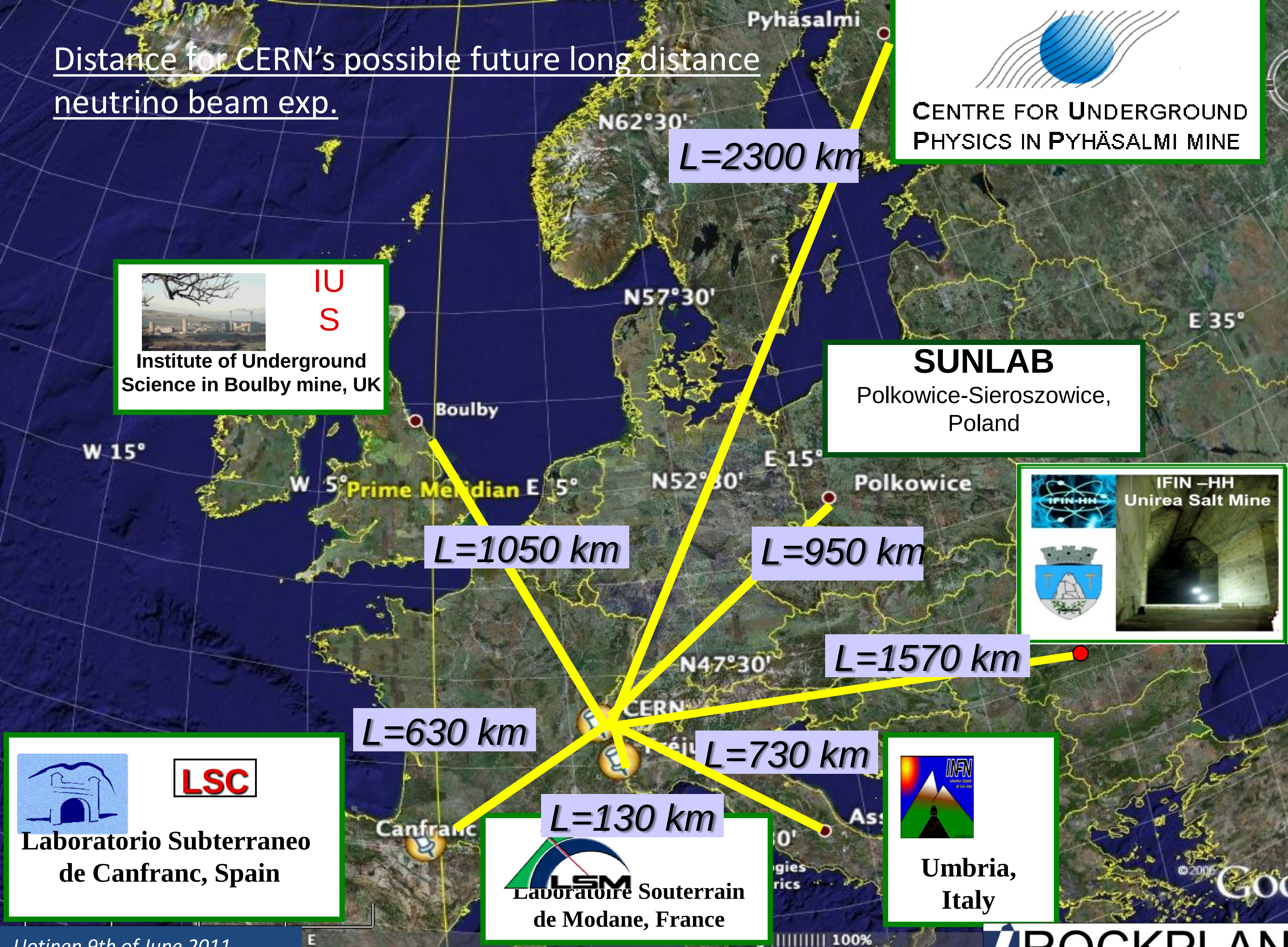
2) to prepare a conceptual design of the required underground infrastructure

3) to deliver a report that allows the funding agencies to decide on the realization of the experiment and to select the site and the technology

Clearance from nuclear plants to avoid reactor neutrino events



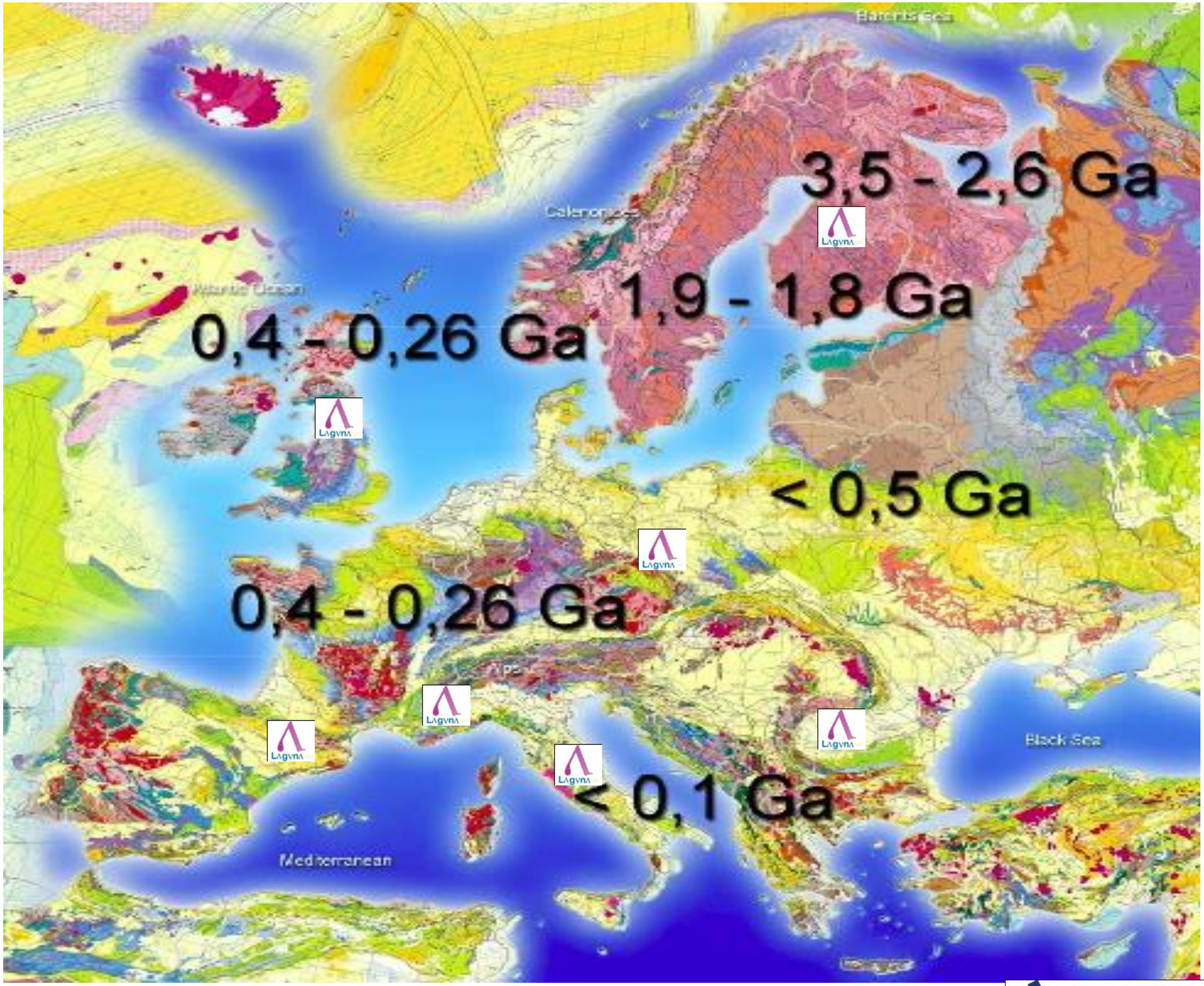
Distance for CERN's possible future long distance neutrino beam exp.



ROCK CONDITIONS

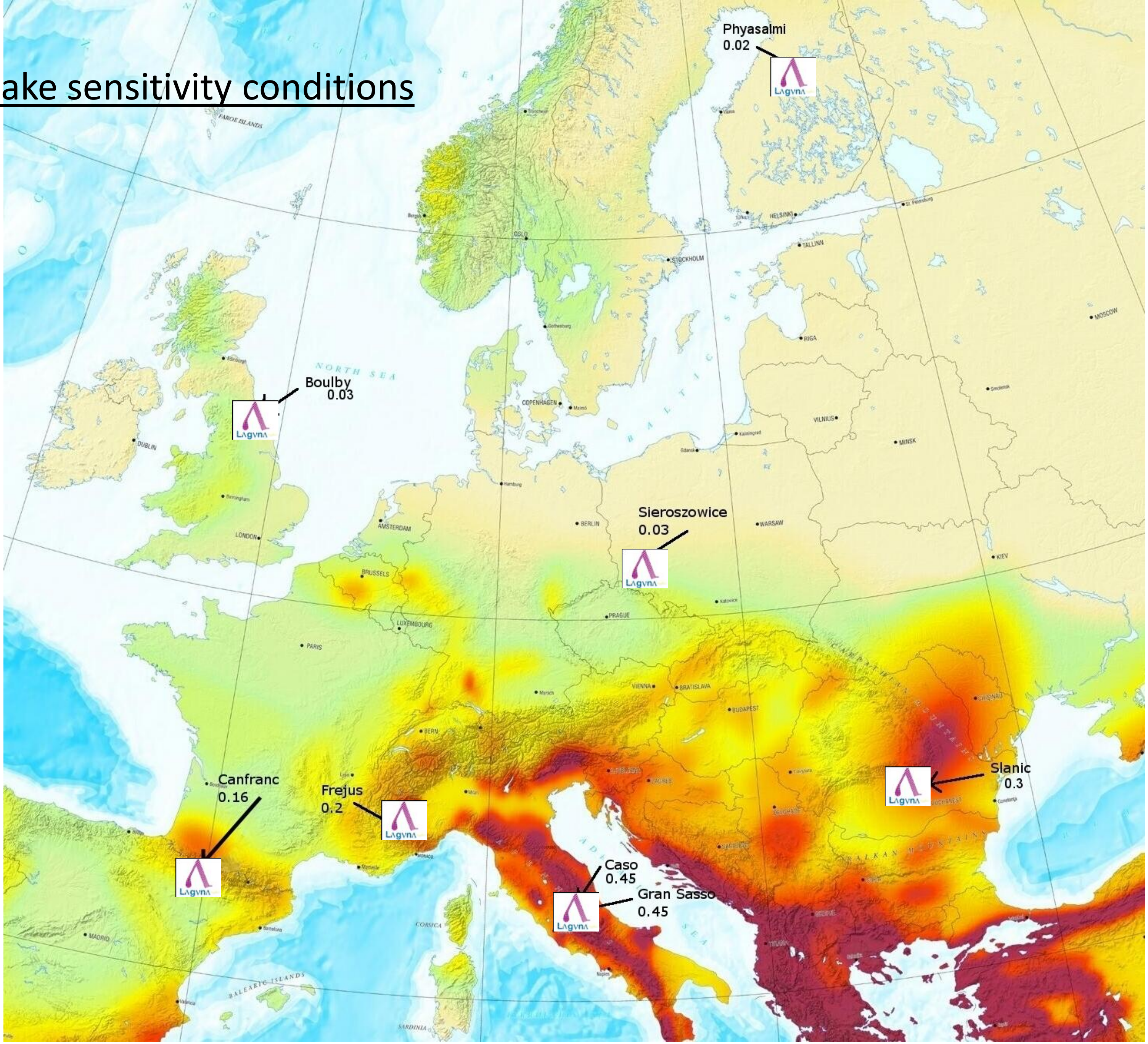
- Geological conditions
- Rock temperature
- Earthquakes
- Hydrological conditions

Geology: stable (ancient) bedrock conditions



ROCKPLAN

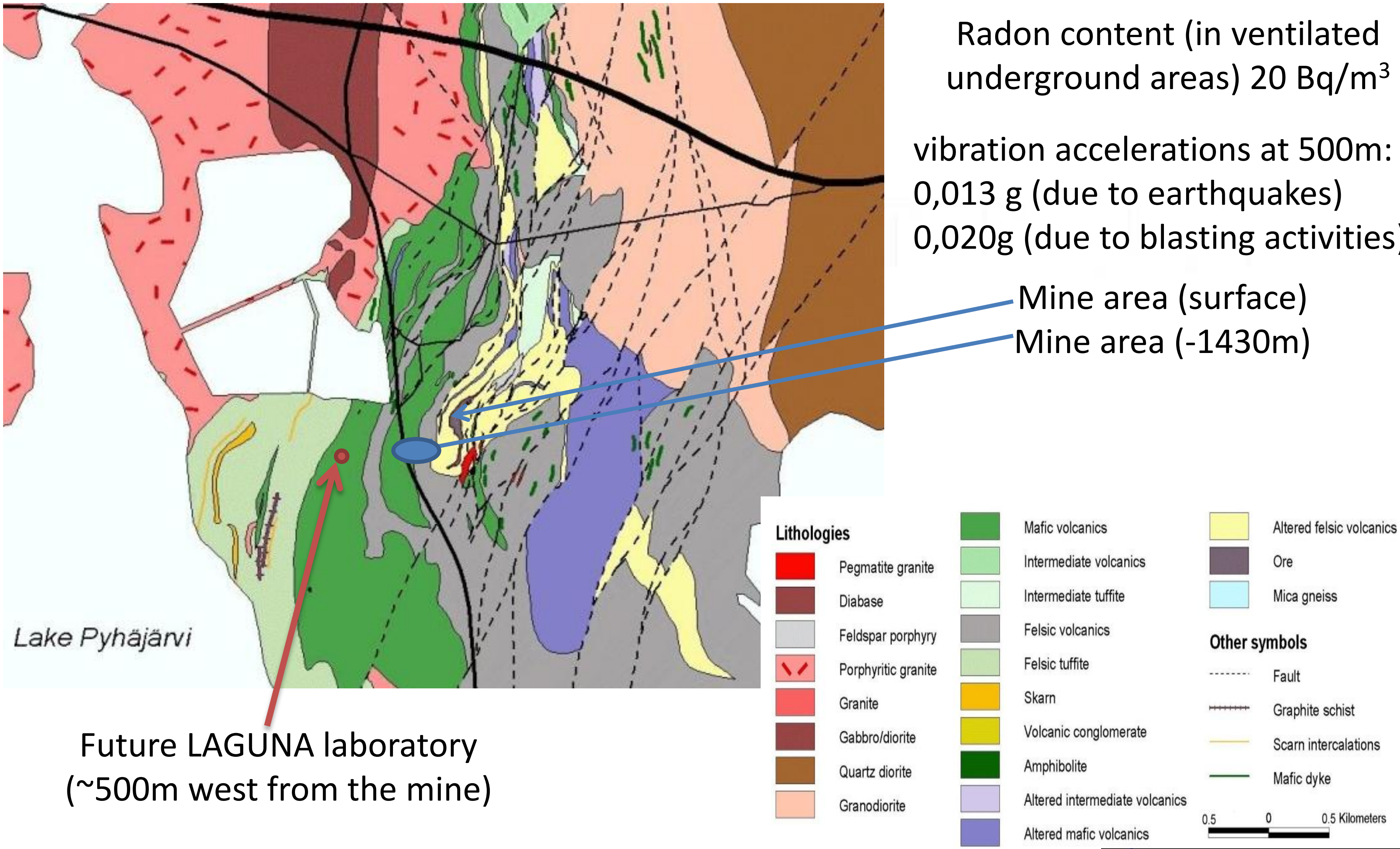
Earthquake sensitivity conditions



Lithological map of the Pyhäsalmi volcanic complex

Radon content (in ventilated underground areas) 20 Bq/m^3

vibration accelerations at 500m:
0,013 g (due to earthquakes)
0,020g (due to blasting activities)



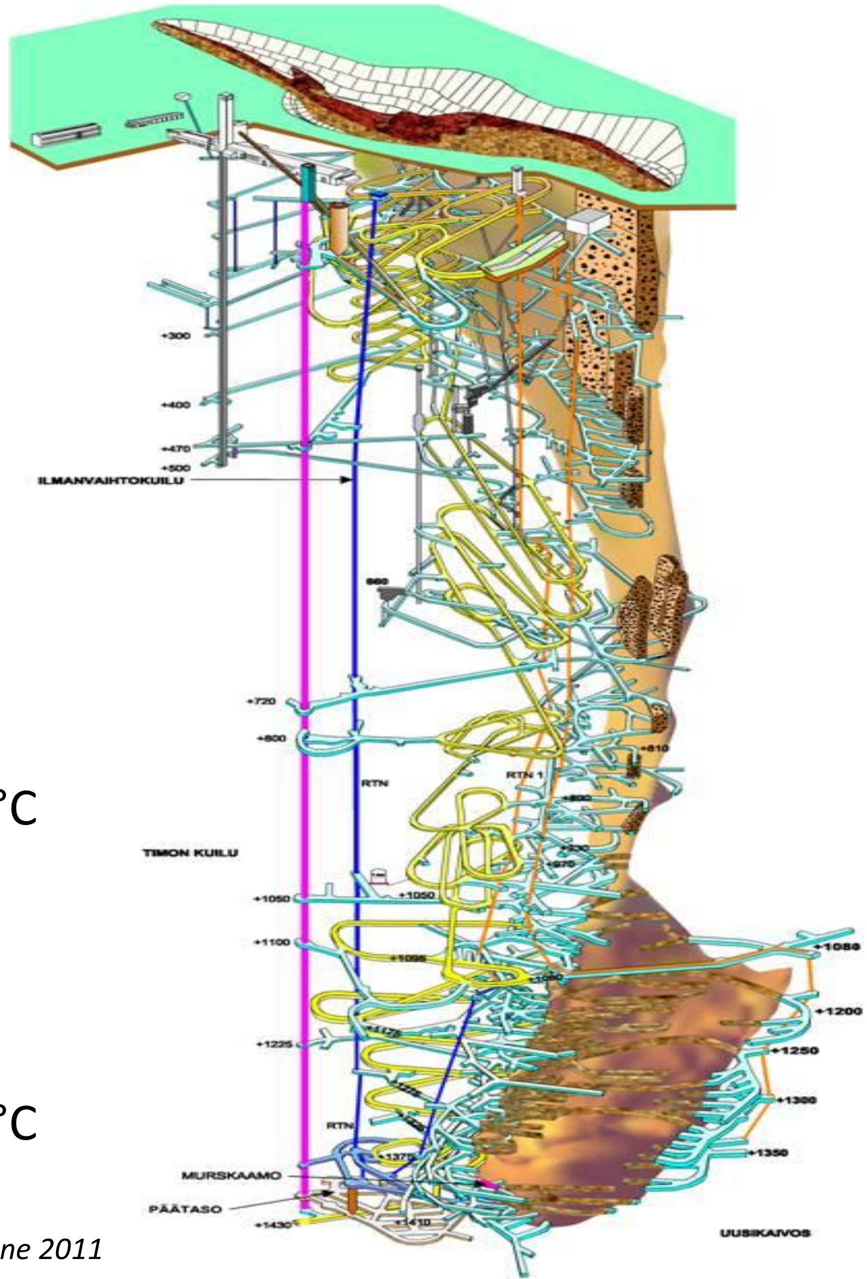
Future LAGUNA laboratory
(~500m west from the mine)

Temperature conditions of in-situ rock

T=5°C

T=16°C

T=22°C



Average air temperatures at surface in Pyhäjärvi are: -9^{o}C (Jan) ... +16^{o}C (July).

Uotinen 9th of June 2011

ROCKPLAN

ROCK MECHANICS

- Rock Strength vs. Rock Stress
- Rock behavior
- Deformations
- Reinforcements needs

Rock strength vs. rock stress (concept level)

Strength =:
- compressive strength from sample testing (i.e. intact rock strength) &
- geological strength conditions (e.g. GSI-value): influence of cracks (like types, density, directions, length, smoothness etc.), stratification, weak zones etc

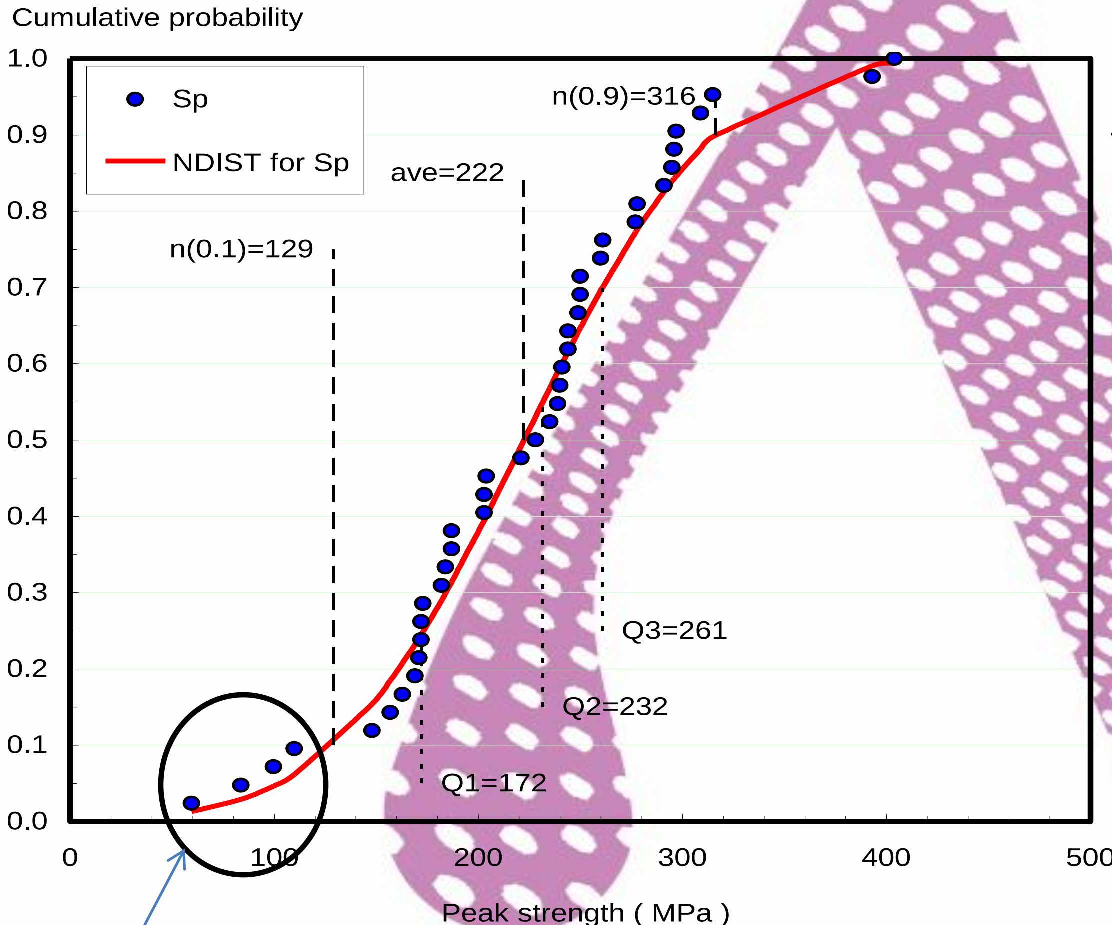
- combined = rock mass strength

Stress =:
- In situ stress situation (level and direction): condition before excavation
- Excavation induced increasing of stress around cavern (mainly tangential stresses)

- combined = stress around cavern

To be analyzed:
- If rock mass strength > stress around cavern = elastic behavior => OK
- If not => failure (plastic behavior, spalling, creep etc.) => challenges!

Rock strength vs. rock stress (Finland)



Peak Strength of Mafic and Felsic Volcanites (intact) σ_{ci} = 232 MPa

Geological Strength Index = 77

Rock mass strength σ_{cm} = 132 MPa

Note: Pegmatite dykes (intact) σ_{ci} = 110 MPa to be avoided

measurements and stress failure observations confirms Rock mass strength σ_{cm} = 132 MPa

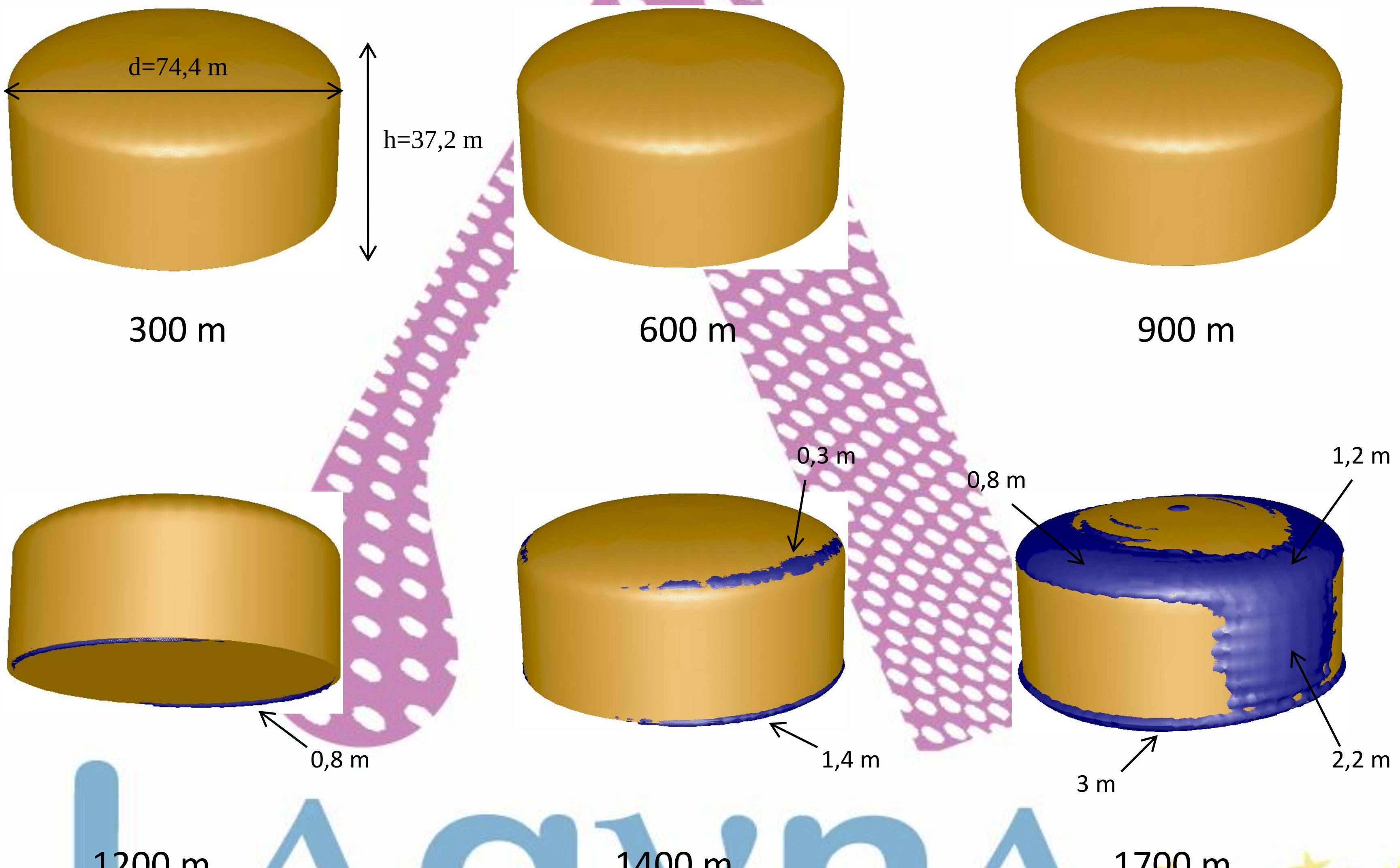
ROCKPLAN

Rock strength at Pyhäsalmi mine (Finland)

Uniaxial compressive strength of intact rock is 200-250 MPa (median 232 MPa) and is comparable to the strength of structural steels (e.g. S235 is 235 MPa)

ROCKPLAN

GLACIER – Stress Induced Damage (Spalling)



GLACIER – Stress Induced Damage (Spalling)

GLACIER				
	Depth (m)	**Spalling (σ_1-$\sigma_3 \geq$ 132 MPa)**	Max σ_1-σ_3 (MPa)	**Spalling depth (m)**
	300	**No**	46	**-**
	600	**No**	88	**-**
	900	**No**	130	**-**
	1200	**(Yes)**	164 (171)	**(0,8 m)**
	1400	**Yes**	191 (199)	**0,3 m (1,4 m)**
	1700	**Yes**	230 (241)	**2,2 m (3 m)**

- **Based on current rock mechanical information and from the point of view of rock spalling GLACIER can be excavated 1200 m below ground surface level as such (or up to 1400 m by using elliptical shape).**

- Max σ_1-σ_3 values are indicative and only meant to illustrate the largest values that strain element(s) located on the wall or ceiling (usually loads that have accumulated on a single small element or point)

- The bracketed values in the table are the largest values of the elements located on the floor (due to sharp edge)

- The spalling depths are suggestive and the arrows in the pictures just illustrate different spalling areas, not the exact locations of the given spalling depth

- Results in the sharp edges at the bottom of the excavation shapes are visualized just for comparison – results can be optimized with a rounded shape

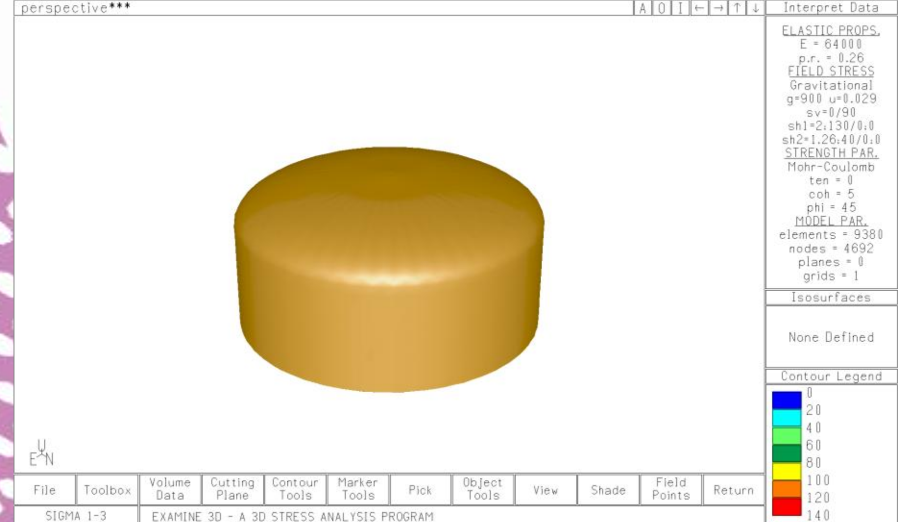
- As presented all the shapes can be optimized from a rock mechanical point of view by using elliptical shapes relative to the in situ stresses (increases cross-sectional area considerably)

Rock strength vs. rock stress (Finland)

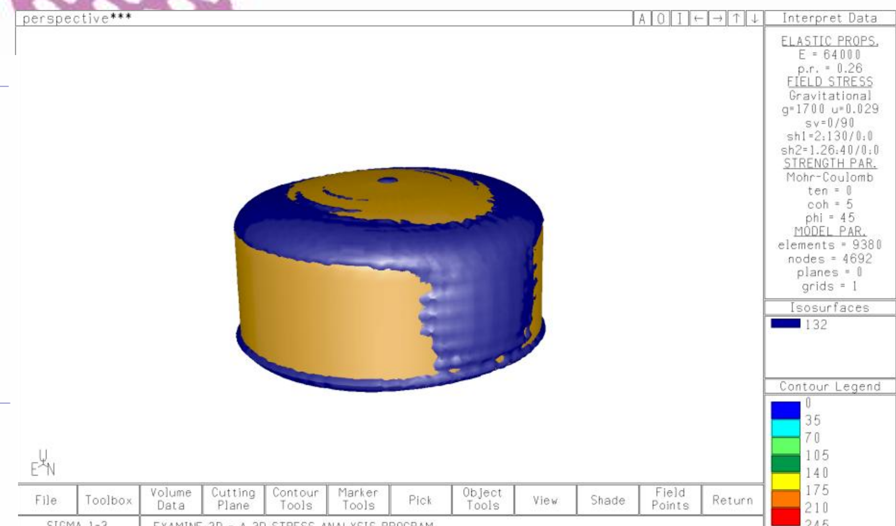
In situ stress (before excavation)

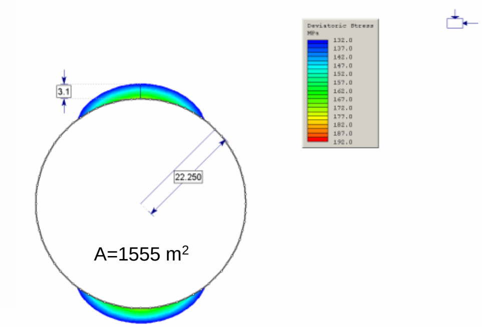
Depth (m)	*σ_{H1} (MPa)*	*σ_{h2} (MPa)*	*σ_v (MPa)*
900	52	33	26
1100	64	40	32
1400	81	51	41
2000	116	73	58

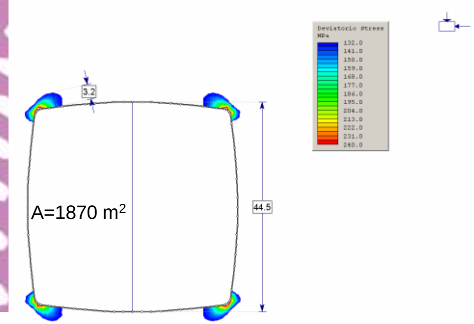
Major principal stress is horizontal and bearing to N-W (310° clockwise from N).

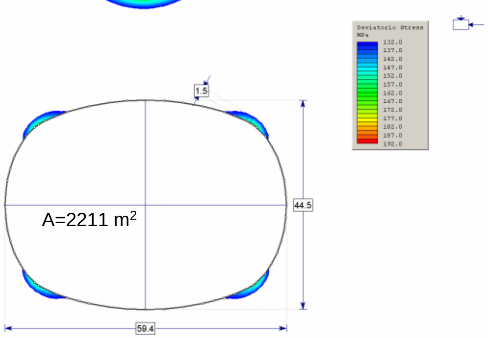


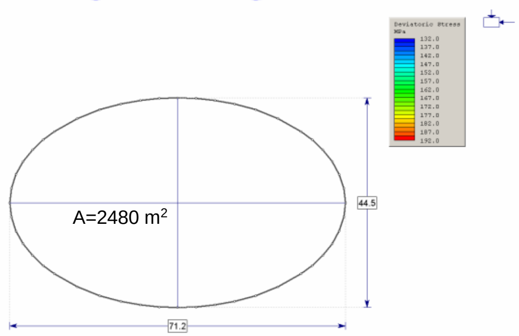
GLACIER results at -900m (up) & -1700m (down)











LENA results at -1450m (left)

GLACIER – Reinforcement solution

Current solution (at -1440 m level main halls): 50 mm steel fibre reinforced shotcrete + 2,2 m long steel rebar bolts & steel mesh + cable bolts & 50 mm of shotcrete

For GLACIER:

50 % Cable bolts 20 meters # 2,4 meters
50 % Cable bolts 12 meters # 2,4 meters
(combined #1,7 m)

6 m immediate bolts

150 mm shotcrete with steel mesh

Total of 4000 rock bolts (29 km) and 11500 m2 (1200 m3) shotcrete

ROCKPLAN

INFRASTRUCTURE AT SITE

- Shafts and access tunnels
- Rock disposal
- On surface infrastructure
- Necessary new infrastructure

Present Infrastructure at site

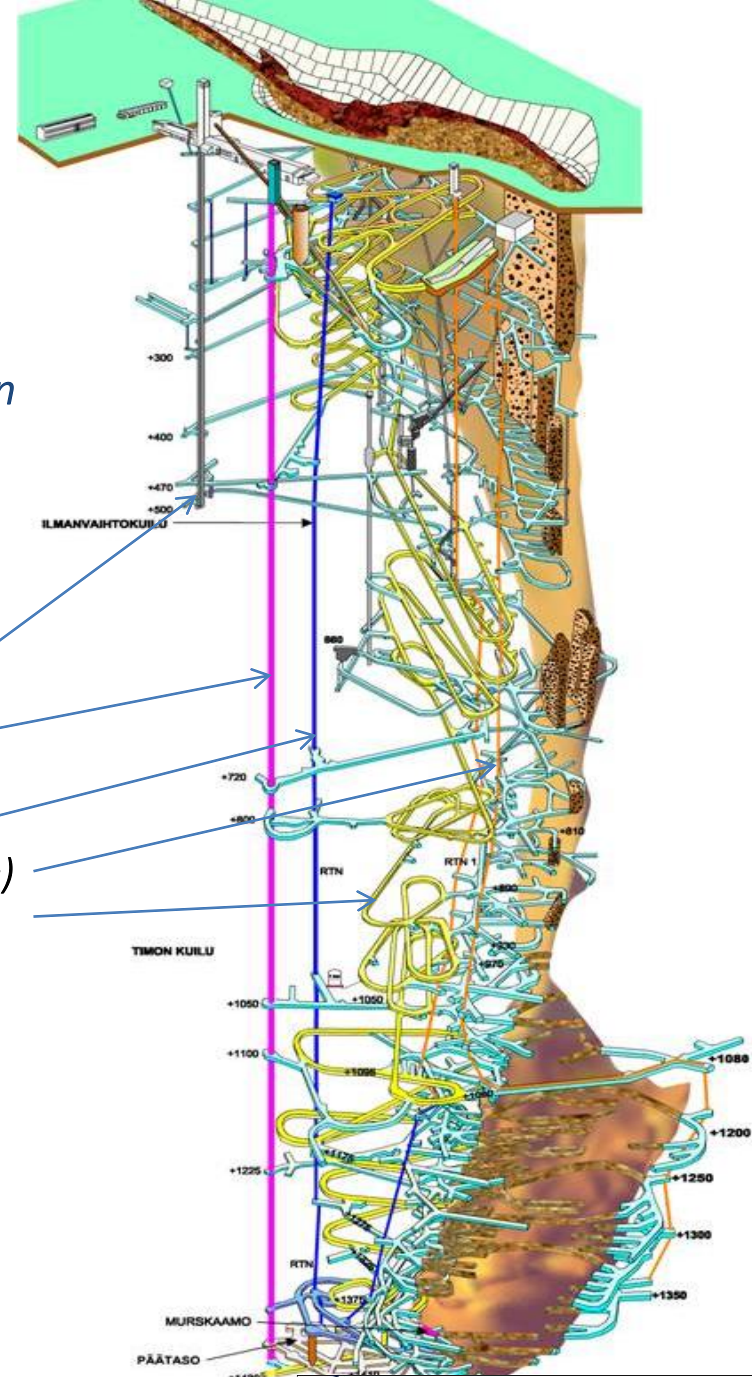
Main challenge:

Not to disturb mine production

Finland

- *Old main shaft (to -500m)*
- *Main shaft (violet)*
- *Inlet ventilation shaft (blue)*
- *Outlet ventilation shaft (orange)*
- *Decline / access tunnel (yellow)*

Uotinen 9th of June 2011



ROCKPLAN

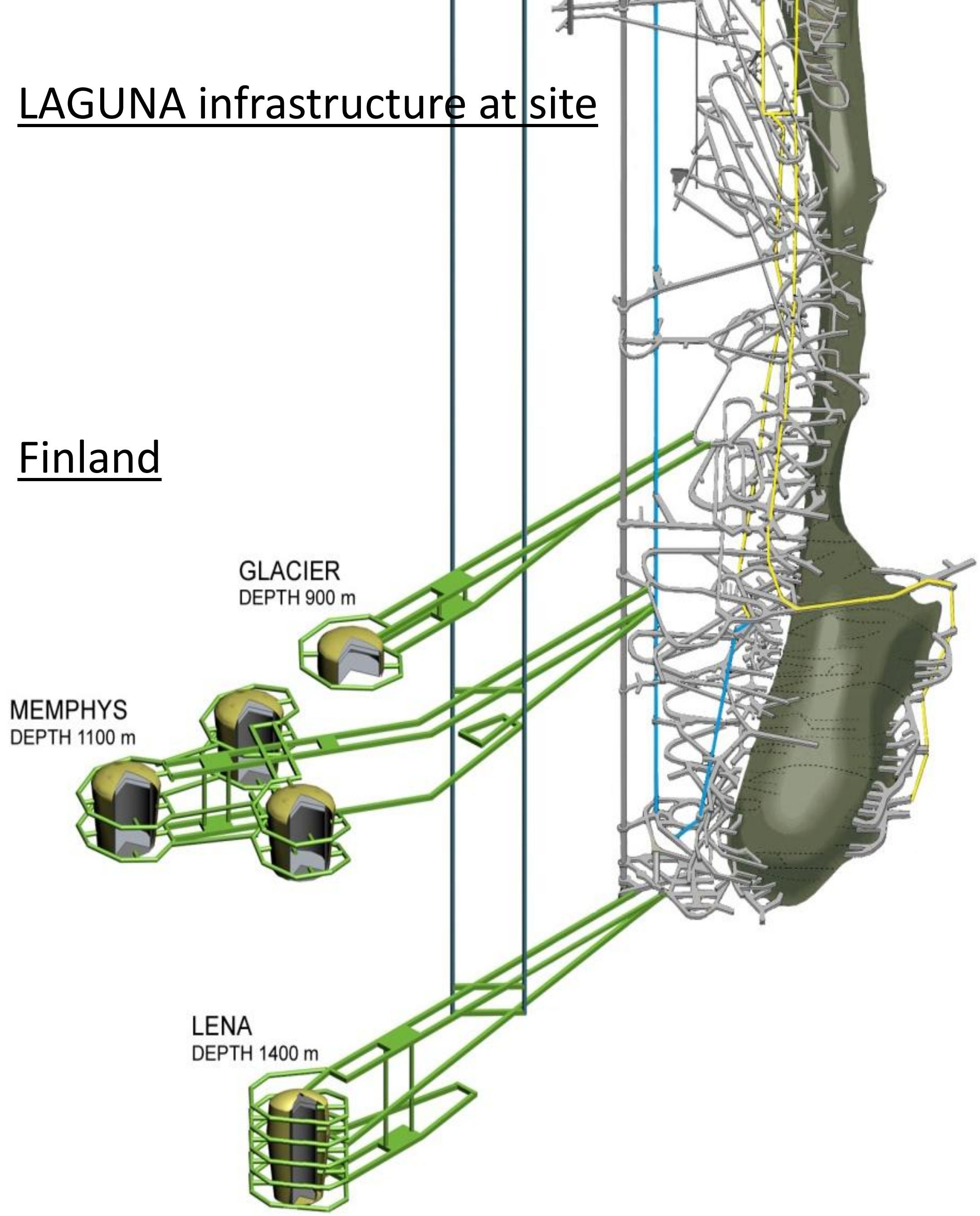
LAGUNA, External installation / on surface constructions

Primary infrastructure (primarily needed and therefore also part of Laguna costs)

railway connection	is present to the Mine area and is in good condition
railway yard	is present on the Mine area and perfectly suitable for Laguna needs (2nd biggest of Finland)
road infrastructure	is present and in good shape (nearby is the main north south corridor "Road nr. 4" between Oulu and Helsinki)
harbor	situated in Kokkola only 160km away and is connected by rail with the site
electric infrastructure	is present at site (110 kV power supply) and sufficient also for Laguna purposes
water availability	Pyhäjärvi lake nearby with a capacity of 0.83 km^3 and the water quality is good
transmission station	the Mine has its own electricity supply, but it is needed to construct the power transmission station for construction and operation on the surface
pipe line	fully operating fuel dry line operative in the Mine between surface and -1400; similar solution of these facilities to be used
airfield	minor airfield is present at 10km distance (main airports located in Oulu and Jyväskylä at 170km distance)
parking space	present at the Mine area (large enough also to host trucks and other bigger vehicles)
offices / lunch room	present at site but in use for the Mine; new office to be built, that also has room for seminars and other conventions as Laguna starts operating

LAGUNA infrastructure at site

Finland



Main purpose of the infrastructure

- ***Sufficient*** *(to conduct the experiment)*
- ***Efficient*** *(cost & process effectiveness)*
- ***Safe*** *(during all phases)*

Main aspects of the infrastructure

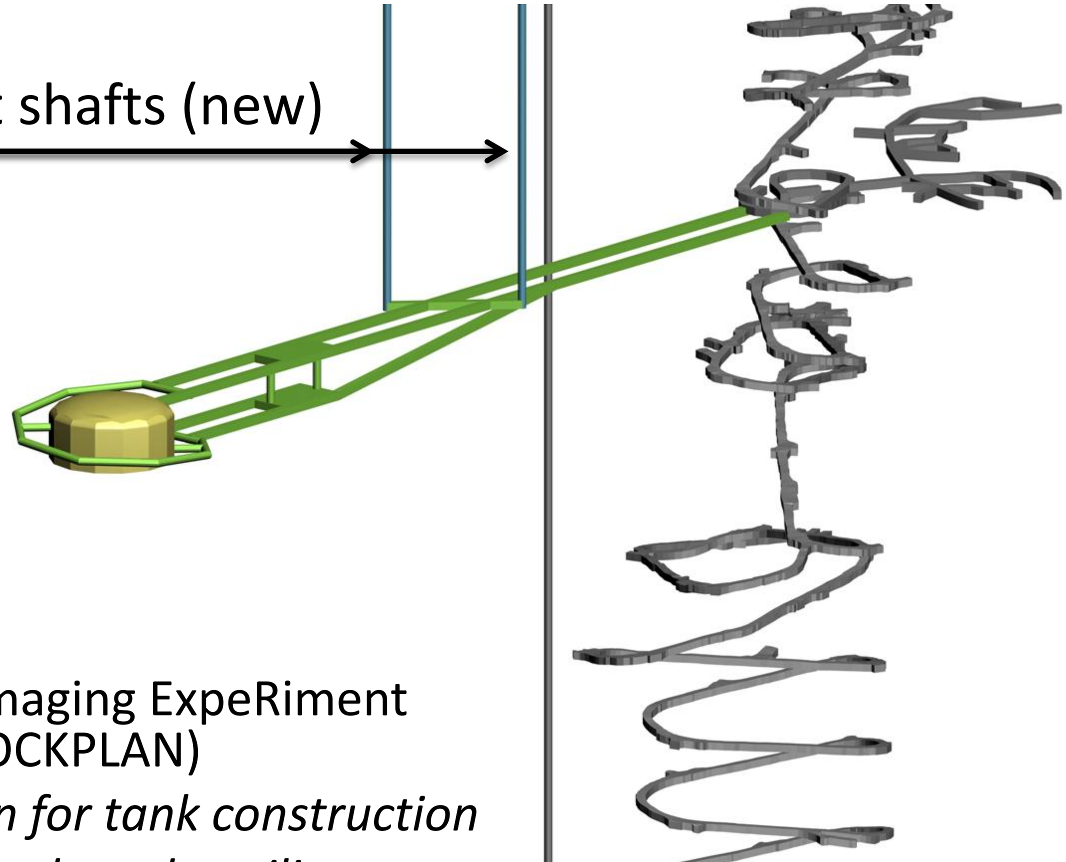
- *good excavation strategy*
- *efficient rock disposal*
- *no disturbance with hosting site*
- *sufficient fresh air inlet*
- *effective outlet of return air*
- *safety*
- *supply routes for construction*
- *storage of material*
- *quality control of material at the vicinity*
- *supply route (pipe lines) for liquids*

RESULTS

- PRINCIPLE LAYOUT
- COST ESTIMATES
- CONSTRUCTION TIME

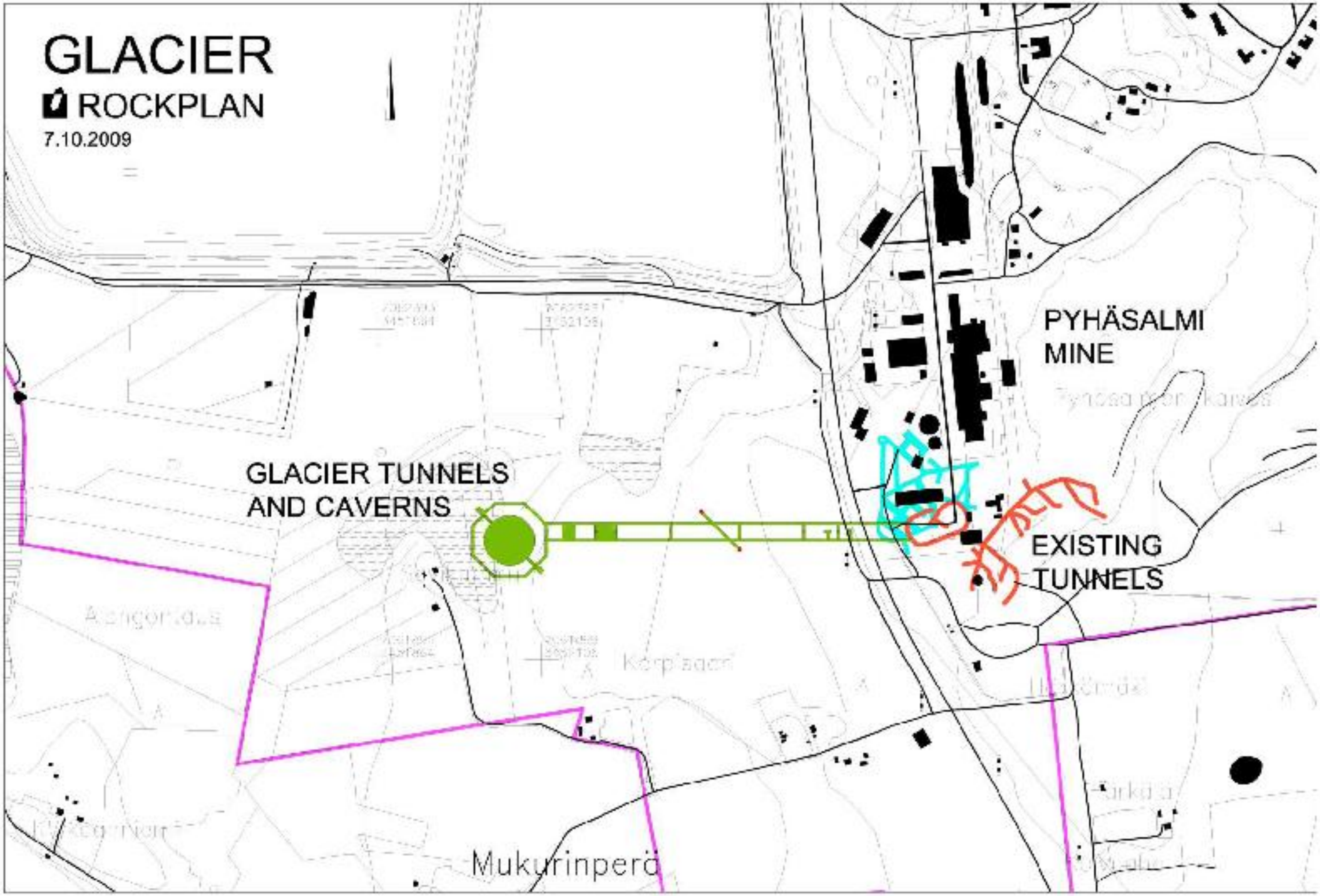
GLACIER at 2500 m.w.e.

Ventilation inlet & outlet shafts (new)

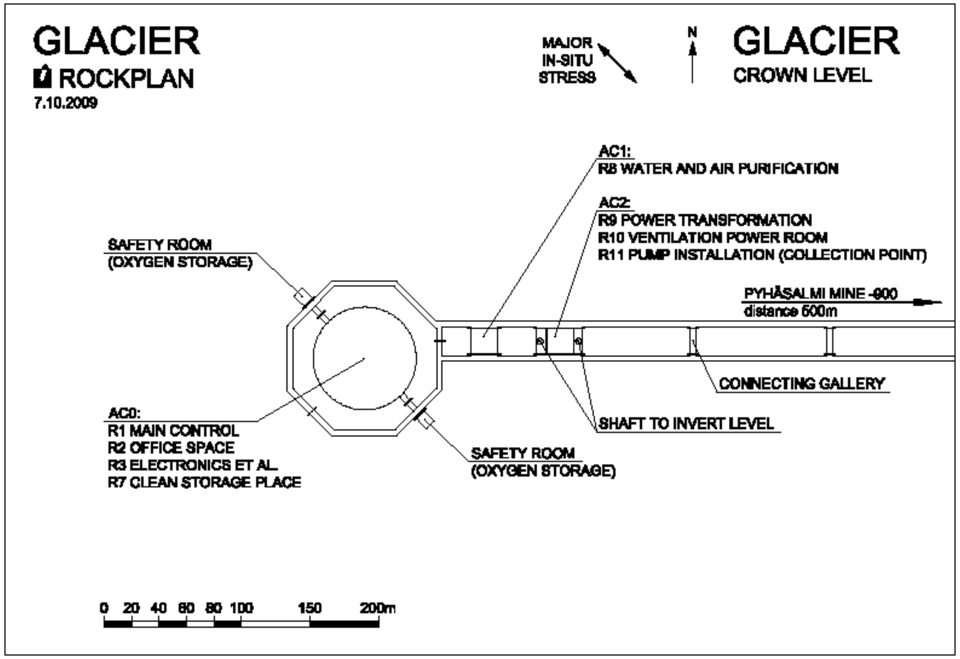


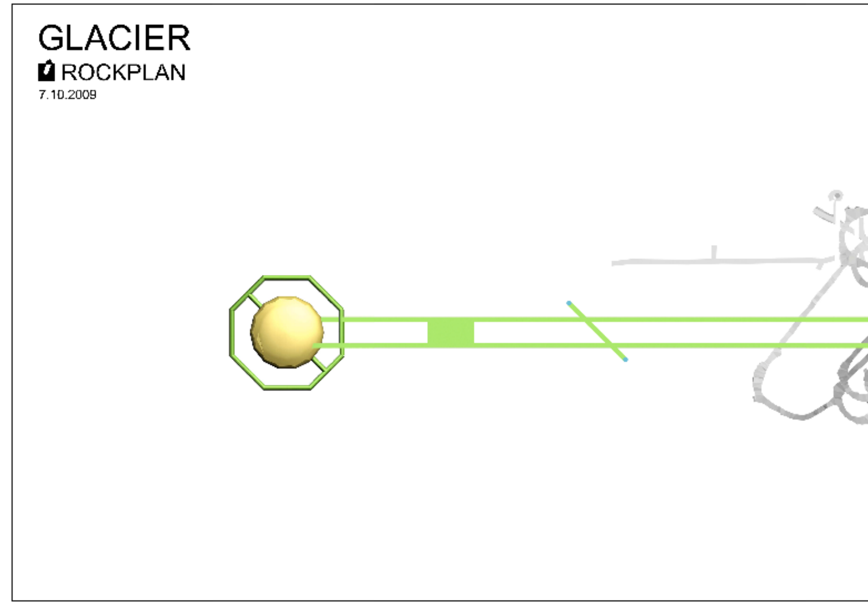
Giant Liquid Argon Charge Imaging ExpeRiment (artistic impression by ROCKPLAN)

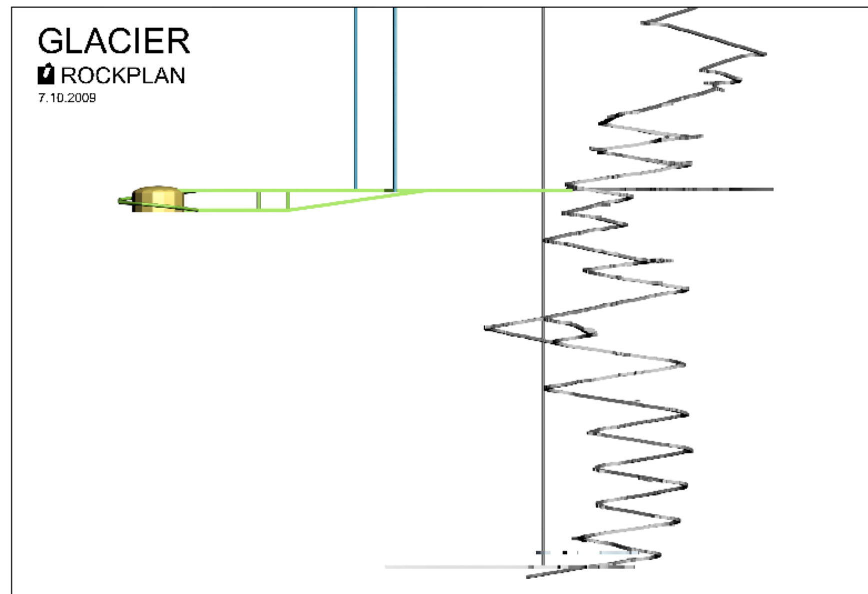
- *yellow* *new cavern for tank construction*
- *green* *access tunnels and auxiliary rooms*
- *blue* *new shafts*
- *grey* *existing infrastructure at 900m*

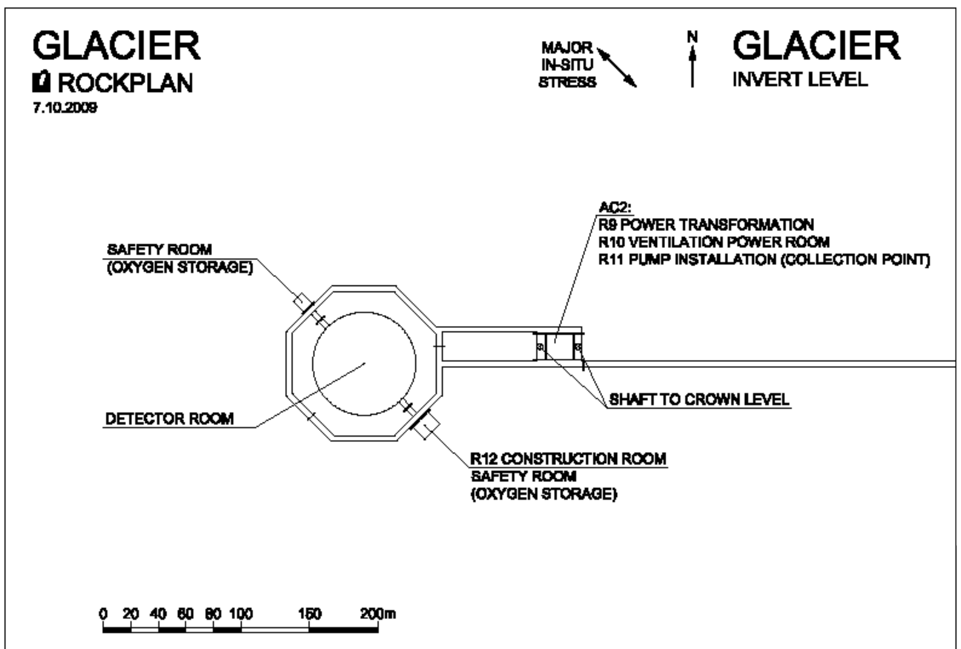

GLACIER
ROCKPLAN
7.10.2009
PYHÄSALMI
MINE
GLACIER TUNNELS
AND CAVERNS
EXISTING
TUNNELS
Mukurinperä

ROCKPLAN









Uotinen 9th of June 2011

ROCKPLAN

GLACIER, cost estimate

Preparation costs

• General & rock mechanical design		2,5 M€	
• Development & consulting service		2,0 M€	
• Site investigations		2,5 M€	
Total preparation costs:			7,0 M€

Excavation costs

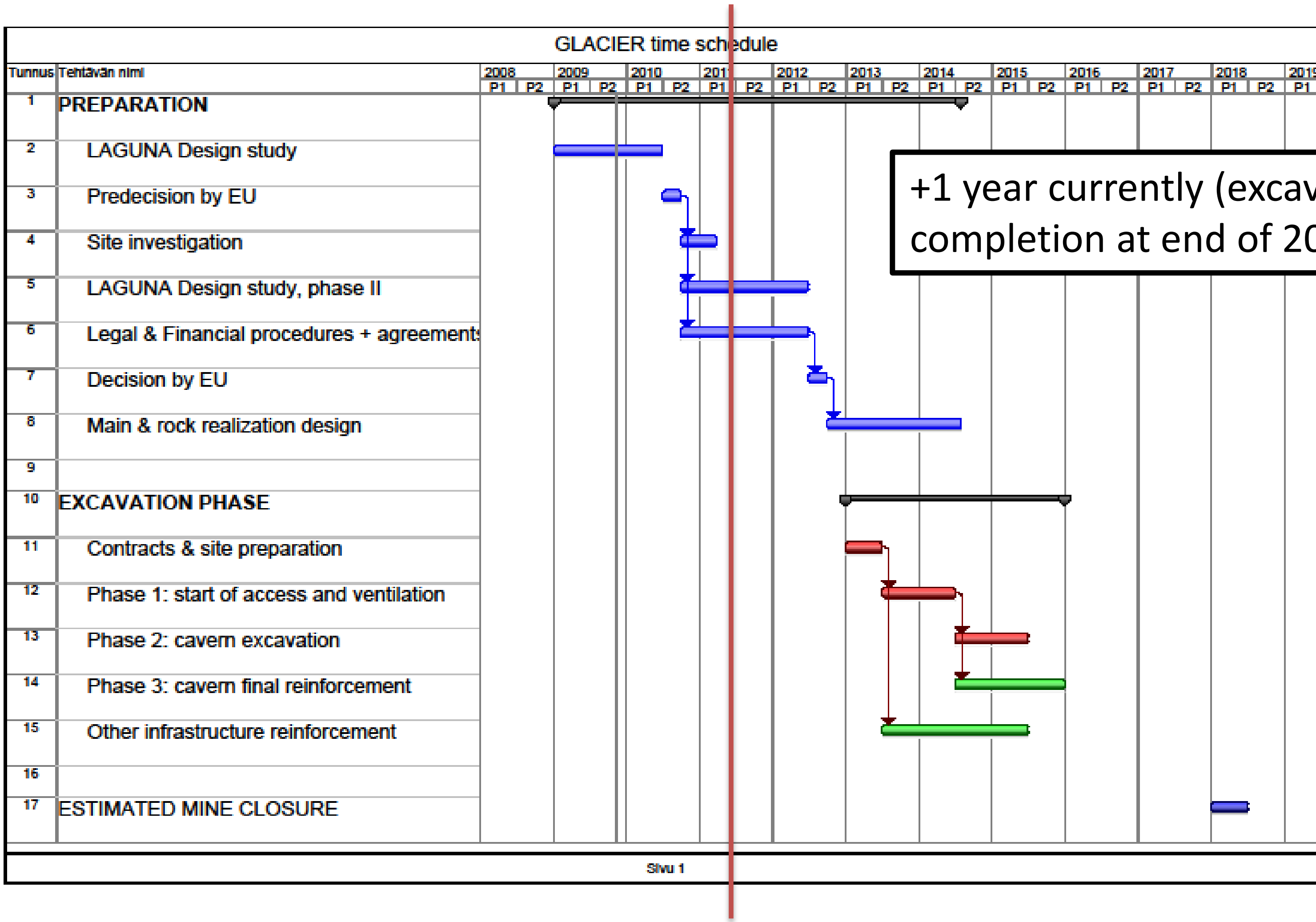
Excavation			
• Main Detector Cavern	156’000 m^3	5,6 M€	
• New tunnels	92’000 m^3	4,1 M€	
• Shafts	13’000 m^3	5,9 M€	
• Auxiliary Caverns	15’000 m^3	0,7 M€	
Excavation additional costs			
• Ventilation, electricity, drainage during excavation		1,8 M€	
• Bulk transport to the existing Mine		0,5 M€	
• Miscellaneous		1,5 M€	
Total excavation	277’000 m^3		20,1 M€

Reinforcement costs

• Bolting, subtotal:	7,0 M€	
• Shotcrete & wire mesh, subtotal:	10,6 M€	
• Other (groundwater & radon ingress prevention measurements)	0,2 M€	
Total reinforcement:		17,8 M€

Total underground infrastructure costs **44,9 M€**

GLACIER, time schedule



+1 year currently (excavation completion at end of 2016)

Overview of costs (FINLAND)

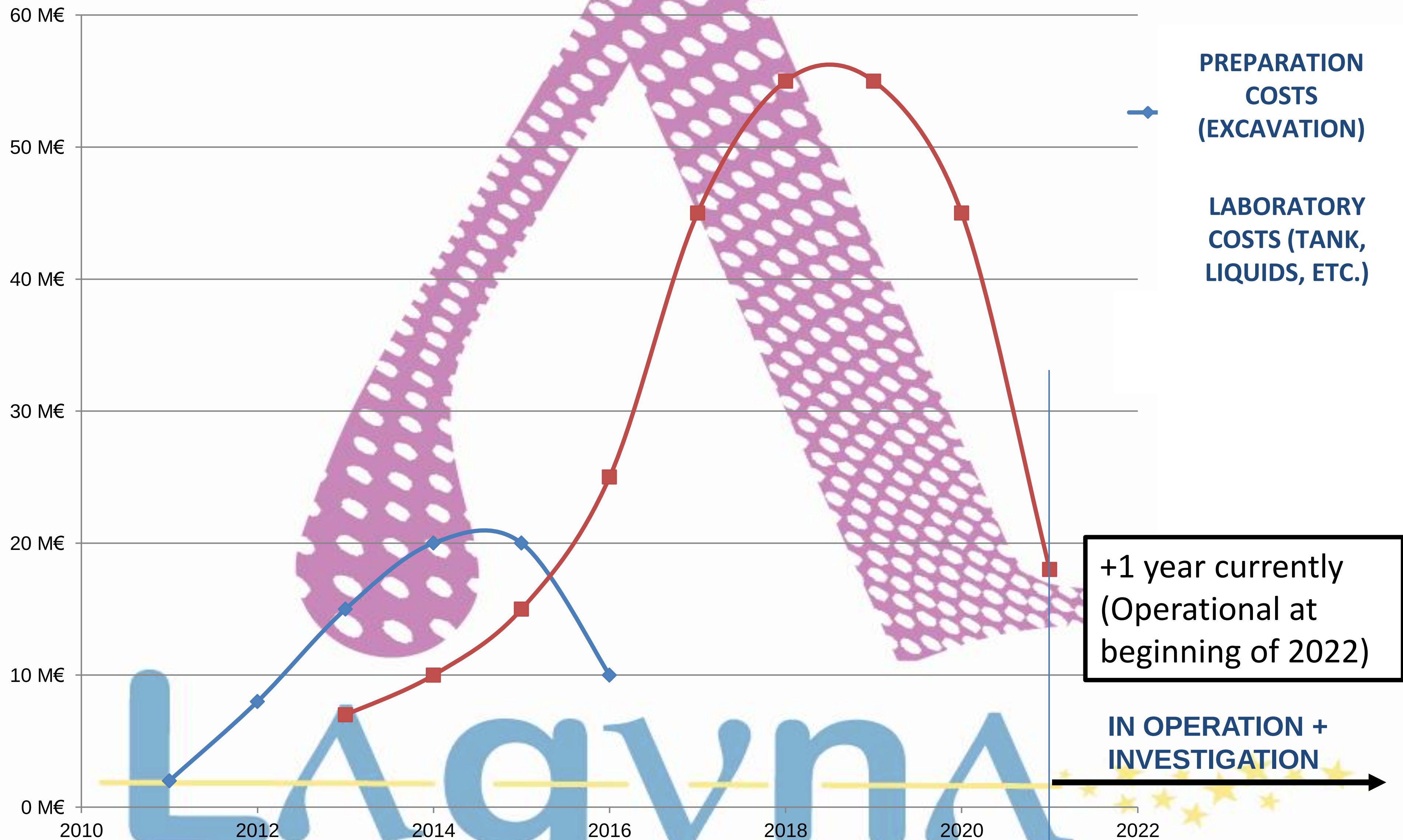
Phase	***GLACIER***	*MEMPHYS*	*LENA*
Site preparation	**45 M€**	125 M€	75 M€
Site investigation *Design, development & managing* *Excavation* *Reinforcements* *Additional (ventilation, bulk transport)*			
Laboratory construction *	**400 M€**	575 M€	275 M€
Tank construction *Auxiliary constructions* *Liquids + handling / cooling* *Sensors (photomultipliers)* *Data handling, electricity etc.*			
**Total ** **	**445 M€**	**700 M€**	**350 M€**

** to be analyzed more thoroughly*

*** without unforeseen, without operation costs*

ROCKPLAN

Construction time and cash flow (FINLAND)



Uotinen 9th of June 2011

Further research needed

- Mine infrastructure upkeep costs if the mine ends production at 2018?
- Is the existing hall system at -650 level suitable to be utilized?
- Could the outlet shaft be replaced by a connection to the existing outlet system?
- Given the latest rock mechanical data, is the -900 level still optimum?
- What is the optimum method for Liquid Argon procurement and delivery?